DEFENSE STANDARDIZATION PROGRAM

CASE STUDY

Joint Tactical Radio System

This case study describes how a DoD team developed the Joint Tactical Radio System (JTRS), dramatically increasing defense communications capabilities, interoperability, and warfighter safety and security, while reducing system life-cycle costs.

Joint Tactical Radio System

One Standardized Radio Replaces Many Legacy Radios

Background and Problem

In combat, the ability to communicate quickly, effectively, and securely can often make the difference between success and failure, victory and defeat, life and death. However, communications problems have plagued nearly every military operation from the earliest conflict to the present day. During military operations in Grenada, for example, combatants on the ground made long-distance telephone calls to Fort Bragg, NC, to relay bombing coordinates to C-130 gunships over Grenada. During that campaign, Air Force units could not communicate with their Army or Marine counterparts. Almost 10 years later, during the Afghan campaign, warfighters experienced similar problems. And in that conflict, the inability to establish direct communications between ground forces and bombers flying overhead resulted in a friendly fire incident at Mazar-e-Sharif. These are but two examples of the many communications and interoperability failures that resulted in lost opportunities, lower efficiencies and effectiveness, and lost lives.

Combat communications have been a problem largely because each military tactical radio had a dedicated function. Consequently, a warfighter needing to communicate with a dozen different functional activities might require a dozen different radios. And the problem doesn't stop there. The legacy radios are hardware based, and most use proprietary designs and components. Consequently, logistics support is complex, and upgrades to add new capabilities or to overcome technical limitations are costly, significantly increasing system life-cycle costs.

DoD recognized that warfighters, whether soldiers, sailors, airmen, or marines, need one common tactical radio system, JTRS, to communicate with one another—a radio system that is compatible with the information-dependent battlefield that DoD planners envision in Joint Vision 2020. To address that need, DoD established the JTRS Joint Program Office (JPO).

The JPO teamed with the military services, the National Security Agency, and the Defense Advanced Research Projects Agency to develop JTRS. The structure of the JTRS team reflects the operational missions and environments in which the system must operate, including ground, maritime, and airborne operations. The Army leads development for ground, vehicular, and rotary wing radios. The Special Operations Command leads the development of hand-held and backpack radios, while the Navy leads development of radios for maritime and fixed-site environments. The Air Force leads development for airborne radios that have specialized size, weight, and power constraints.

Approach

The JTRS team determined that the key to the solution is a software-defined radio that relies on state-of-the-art object-oriented technology and uses a standard open architecture. An object is a packaged set of software code that contains all the instructions to perform or emulate a desired capability. For example, an object can be designed to emulate and be compatible with legacy radio systems. A key benefit of an object-oriented system is its ability to evolve, or expand in functionality by adding new objects to the system. This approach results in faster application development, easier maintenance, enormous scalability, and reusable software.

To develop JTRS, the JPO and other stakeholders began by conducting market research to define what is possible and by observing demonstrations of commercial products. The information gained enabled the team to articulate clear design requirements for JTRS. Also, early in the development process, the JTRS team sought industry's ideas on the technical challenges and identified an evolutionary acquisition approach to move solutions to the field quickly.

The JPO worked with key standardization organizations to ensure international acceptance of a radio communications standard. The JTRS team also involved a broad range of commercial organizations in the development process; the objective was to use the best commercial technologies and to ensure that industry could adapt the open architecture for commercial use, thus harnessing the momentum of industry to keep the architecture current and consistent with future technology developments.

Next, the JPO selected features that maximize the use of commercial open-source standards and developed a software communications architecture (SCA). Finally, the team built and tested the performance of four prototypes to validate that SCA-based products could meet program requirements.

Market Research

The JTRS team used market research to understand software-defined radio technology and the related marketplace and to determine whether an acceptable open-source standard was available to meet operational requirements. The JPO conducted a market survey to gather relevant data about market capability, related production technology, the availability of emerging technology, and costs. The JPO used survey findings to align JTRS program requirements with market capabilities and to improve its acquisition strategy.

Demonstration of Commercial Products

On the basis of its market research, JTRS issued a request for proposals, calling for an open-source approach and asking respondents to demonstrate their experience with and understanding of open systems. In response, several vendors demonstrated commercial applications of software-defined radio technology and the feasibility of open systems and object-oriented technology to satisfy military requirements. The success of such systems clearly demonstrated the advantages a software-driven technology for reducing logistics support requirements and life-cycle costs.

Articulation of Design Requirements

Considering its military customers' needs, the JTRS team defined a clear set of design requirements to provide an unambiguous road map for the system developers. The team articulated the essential system performance requirements, as well as the key design objectives, to ensure that the system could meet both performance and logistics goals.

Standardization was a key element in the JTRS design. Key standardization concepts included the following:

- Use of a standard open architecture, to ensure that a wide array of potential suppliers could contribute to the ongoing support and enhancement of JTRS
- Use of existing standard software objects that represent specific radio capabilities, to ensure compatibility and interoperability with already fielded systems and to provide a reusable, portable executable software application independent of the radio hardware in which it operates
- Maximum use of standard commercial off-the-shelf (COTS) items, to avoid proprietary and government-unique components and thus ensuring lower system

acquisition costs and logistics support costs and enabling system growth based on commercial advances.

Early Industry Involvement

The JTRS team sought to engage industry at the earliest possible moment to bring industry's ideas and talents to bear on the technical challenges and to make the system available to warfighters as quickly and effectively as possible. The JPO chose an industry open forum to share the required system attributes with the potential developer community. This encouraged open discussion between the developers and the team and helped crystallize both commercial interest and commitment.

Evolutionary Acquisition Approach

The JPO identified an evolutionary acquisition strategy for JTRS. This approach enables programs to upgrade system capability and functionality with new commercial technology as it becomes available, and it enables rapid development and fielding because a program office can deploy its system incrementally. Evolutionary acquisition may entail multiple procurements that provide for incrementally fielding viable new capabilities as soon as they are ready.

Ensuring International Interoperability

The JPO worked with the Object Management Group (OMG), an independent not-for-profit corporation that develops vendor-independent specifications for the software industry. A consortium of more than 800 companies, the OMG produces and maintains software standards for object-oriented systems such as JTRS. The OMG consensus process includes general review, commentary, open discussion, and voting. OMG specifications provide a common framework for application

development. Conformance to these specifications makes it possible to develop a heterogeneous interoperable computing environment across all major hardware platforms and operating systems.

The JPO also coordinated its SCA development efforts with the Software Defined Radio Forum (SDRF), an international association of more than 130 companies, dedicated to supporting the development, deployment, and use of open architectures for advanced wireless systems. Coordination with the SDRF was essential to ensure that the SCA would meet commercial and international requirements to become a viable international standard. Endorsement by the SDRF was also a critical step before forwarding the SCA standard to the OMG for consideration and adoption as an international standard.

Broad Industry Participation

The JPO awarded contracts to three industry consortia to develop preliminary SCA definitions and to identify technology issues. These consortia included the major defense communications contractors as well as important members of academia.

The JPO selected the best features from the definitions provided by the consortia and awarded contracts to develop four JTRS prototypes to demonstrate the JTRS architecture. The JPO then selected the definition that best met the SCA development goals and strengthened the definition by incorporating the best features of the other development efforts.

The JPO ensured broad vendor participation by awarding supporting contracts to eight other potential suppliers to provide related services and to validate the SCA's efficacy and flexibility. This early industry involvement helped accelerate broad commercial acceptance of the SCA as a standard architecture for all software-defined radios.

Use of Common Commercial Open-Source Standards

The JPO sought to maximize the use of commercial open-source standards. For example, the chip sets, communications bus, system interfaces, and electrical hardware are common COTS parts. Developers wrote most of the JTRS software using C++, a standard commercial programming language. Overall, about 95 percent of JTRS hardware and software involves common commercial standards. This extensive use of commercial open-source standards will enable broad-based contractor support for JTRS.

Testing

The JPO established the JTRS Technology Laboratory (JteL) to undertake conformance testing to ensure that the JTRS software and hardware could meet defense requirements

and to certify their quality and compatibility with program goals. The JteL, Joint Interoperability Test Command, and National Security Agency share responsibility for JTRS testing. They each test and certify the JTRS operating environment and each JTRS software object, called a waveform, to ensure that it complies with technical, interoperability, security, and portability requirements across the various user platforms.

Outcome

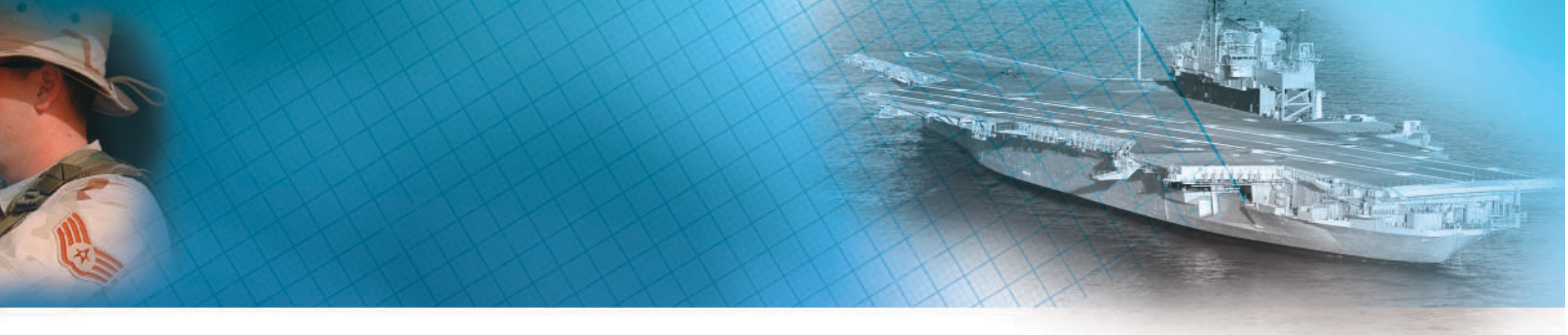
As a result of the work of the JPO and other JTRS stakeholders, DoD now has a common tactical radio system that dramatically increases the capability of the warfighters to communicate with one another—independent of echelon, location, or situation—greatly improving the probability of victory and most certainly saving many lives. The JTRS will dramatically improve the capability and interoperability of the fighting forces and the ability of logistics elements to support them.

JTRS uses a revolutionary new software-defined radio technology that makes radios more like programmable computers. Adding a new capability to a JTRS radio is simply a matter of loading a new program. In addition, the JTRS SCA is a standard open architecture that promotes interoperability; simplifies technology insertion; facilitates system upgrades; and enables software reuse, scalability, and extendibility. The SCA provides functionality in multiple domains to support airborne, fixed, maritime, vehicular, dismounted, and hand-held operations. It also supports multiple radio bands and multiple modes, enabling the JTRS radio family to replace nearly all legacy radios operating between 2 MHz and 2 GHz and to interoperate with these radios across multiple different networks.

The JTRS SCA provides multiple levels of security and enables the interoperability essential for the evolving network-centric tactical military environment. JTRS accommodates both the old networking protocols and the emerging wideband networks capable of transmitting voice, video, and data. Because JTRS is programmable, it can be upgraded or new functionality added simply by downloading a new program. The impact on the logistics system is potentially enormous.

Software-Defined Radio Technology

A software-defined radio is one in which radio capabilities are defined by object-oriented programs and not by hardware. Each object, or waveform, contains all the instructions to emulate a desired radio capability. For example, one waveform object can enable JTRS to function as a satellite communications (SATCOM) radio system, while a different waveform object will emulate a single



channel ground and airborne radio system (SINCGARS). This enables JTRS to interoperate with any legacy radio system simply by loading the waveform that defines the functionality and characteristics of the desired legacy radio. A single JTRS could replace numerous different legacy radio systems simply by having and using an object-oriented waveform for each legacy radio. The software underpinning of JTRS enables users to reconfigure JTRS networks for a new or different mission within 15 minutes—a feat impossible with legacy radios, except by deploying multiple different radios.

Hardware independence is what makes software-defined radios revolutionary. Users can change radio capabilities without changing the radios. In other words, software-defined radios are essentially computers capable of using the same waveforms regardless of platform—aircraft, vehicle, or hand-held. The user simply loads or switches to the software object that provides the desired capability—much like loading applications on personal computers.

Software-defined radios have compelling advantages over legacy radios. They minimize the operational impact of system upgrades—users in the field can upgrade the radio without returning the radio to a technician, repair shop, depot, or the manufacturer. Inexpensive software objects replace expensive hardware components, dramatically reducing acquisition cost, logistics costs, and supply chain dependency. New technologies, new capabilities, and performance enhancements rapidly and incrementally improve the radio system, through software downloads, independent of the underlying hardware.

JTRS radios are packaged in a number of different ways to suit unique operating environments and applications, but the heart of every radio uses the same common standards, the operating computer architecture inside each radio and the software waveform objects that defined each required capability.

JTRS Capabilities

JTRS combines the functionality of numerous single-function radios used by the military services into a single interoperable family of radios. The radio even knows when it is being jammed and can automatically take action to avoid being jammed. JTRS can receive and store transmissions, it has a self-diagnosing system test capability that limits technical support requirements, and it has network-based security features.

Standardized Open Architecture and Modular Design

The Tri-Service Open Systems Architecture Working Group, a defense organization that

promotes an open-source approach for major defense system acquisitions, defines open systems as

> Systems that implement sufficient open standards for interfaces, services, and supporting formats to enable properly engineered components to be utilized across a wide range of systems with minimal changes, to interoperate with other components on local and remote systems, and to interact with users in a style that facilitates portability.

Open architecture, based on standards developed or adopted by recognized standards bodies, uses well-defined and nonproprietary interfaces and protocols, and it provides for upgrades or expansion with minimal impact on the system.

JTRS uses a standardized open architecture and modular design to deliver voice, video, and data communications, as well as network functions, all from a single communications platform. The JTRS open architecture has enormous potential for cost avoidance through hardware and software reuse, commonality of spare parts, and simplified training. A single family of JTRS radios will eliminate or replace about 750,000 legacy radios, resulting in dramatic cost savings in acquisition, logistics, training, operations, and maintenance.

Global Positioning and Cross-Banding Capabilities

Innovative JTRS network features, combined with built-in global positioning system (GPS)

capability, will give warfighters the necessary situational awareness to accomplish difficult missions and avoid becoming lost behind enemy lines. The JTRS cross-banding capability will enable a soldier to receive input on one channel, such as the SATCOM network, and relay it to other warfighters on another network, such as SINCGARS. This radio capability has never existed before.

Simplified and Standardized Interfaces

The JTRS team simplified and standardized the JTRS interfaces to ensure system compatibility with other equipment within the operational environment. Standardized interfaces minimize the impact of integrating JTRS in existing platforms and make it easier to use during joint operations with coalition partners. To ease integration, the team developed an installation kit that includes domain-specific interfaces (maritime, ground, airborne, fixed, and hand-held) to ancillary equipment. These standardized interfaces will produce significant savings over the life of the program.

Standard Architecture

The JTRS architecture supports DoD's objective of network-centric warfare at the tactical level. Network-centric warfare requires a global information grid, an interconnected end-to-end set of information capabilities, associated processes, and people to manage and provide information on demand to warfighters. JTRS plays an important role in achieving this objective. A key development goal was to enable a networked system that can operate between and across organizational and geographical boundaries.

Interoperability within NATO

To ensure JTRS interoperability with NATO members, the JPO worked with NATO's Consultation Command and Control Board Communications Network and its ad hoc radio working groups to develop new NATO standards. To support worldwide deployment, the team made certain that JTRS complies with applicable national and international spectrum allocations, regulations, and standards.

With its standard open architecture, JTRS can adapt rapidly to changes in frequency spectrum allocations. This capability is critically important abroad where, for example, a frequency used in the United States by emergency services could send launch signals to another nation's weapon systems with catastrophic consequences.

Interoperability with Civilian Radios

JTRS can operate on civilian radio frequency bands. This important capability would have

aided local first responders after the attack on the Pentagon when they needed to communicate with defense personnel. As the number of more distant state and federal second responders swelled to over 900, radio communications and interoperability seriously deteriorated. Emergency response planners had not adequately considered the impact of inadequate communications standardization in their planning. Local first responders in many metropolitan jurisdictions cannot communicate easily with their federal counterparts or other key players because their radios operate on different frequencies. JTRS standardization and easy reconfiguration helps solve this problem.

Tactical Mobility Across Diverse Networks

Operational independence requires continuity of communications service for mobile users as they change locations and network connectivity making the communications infrastructure as mobile and dynamic as the warfighter. JTRS standards ensure that hand-held and mobile radios can easily and transparently transfer between networks as they move.

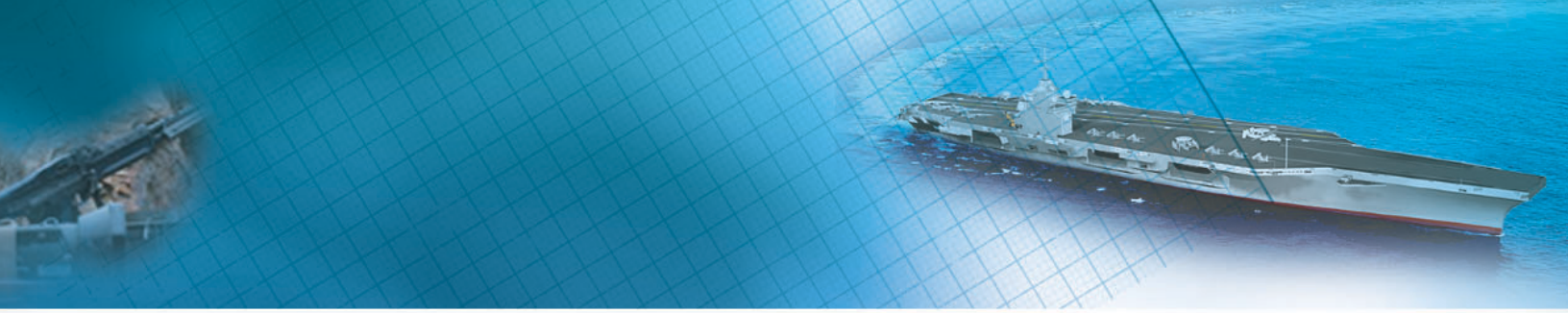
Reliability and Maintainability

The JTRS team's extensive use of proven COTS parts resulted in a highly reliable system with a 96 percent operational availability. Built-in test and system diagnostics ensure high JTRS maintainability. That in turn reduces the need for field maintenance personnel and lowers the logistics system costs and footprint.

Benefits

Many benefits flow from JTRS standards and standardization, including the following:

- *Interoperability.* Overall, force interoperability depends on joint tactics, techniques, and procedures, all facilitated by the JTRS communications capability. Increased interoperability among units, services, and organizations is made possible by using standard waveforms and cross-banding that enables the user to simultaneously communicate across multiple systems, networks, and channels. JTRS will increase interoperability with foreign (combined and coalition) partners by providing the capability to use multiple international communications media and networks.
- *Warfighter safety and security.* JTRS improves warfighter safety through its built-in GPS capability, encryption, and security features such as rapid radio frequency shifts. It improves security support by the sharing standard cryptologic components. JTRS is equipped with embedded programmable cryptographic capability that will eliminate the need for external cryptographic hardware assets and simplify the transmission of encrypted information.
- *Logistics support.* Standardizing on a single family of radios based on common hard-



ware and software platforms will result in the discontinuation of numerous new and legacy radio programs. This will reduce maintenance, training, and support expenditures. JTRS makes possible a reduction in radio support requirements by decreasing the number of unique radio sets required and maintained by DoD. The JPO estimates that the logistics footprint for legacy radios is 10 times larger than it will be after full JTRS deployment. Hardware and software components that are common across implementations reduce the logistics tail and decrease life-cycle costs. Because JTRS is 90 to 95 percent based on common parts, DoD will reap economies-of-scale benefits—common testing, fewer unique parts, and decreased program expenditures over time.

- *Development.* Having one large radio program rather than many small programs enables DoD to benefit from the economies of scale associated with program rationalization. Significant cost avoidance and savings will accrue from avoiding duplicative development and procurement efforts, as well as from the use of common parts, software reuse, competition among multiple industry vendors, and simplified systems integration requirements.
- *Battlefield awareness.* JTRS improves battlefield awareness by enabling seamless communications across the field of operations. Communications both within the battlefield and between battlefield participants and external elements is vastly improved.
- *Homeland security and public safety.* JTRS improves homeland security and public safety by enabling interoperable communications among federal, state, and local first responders.

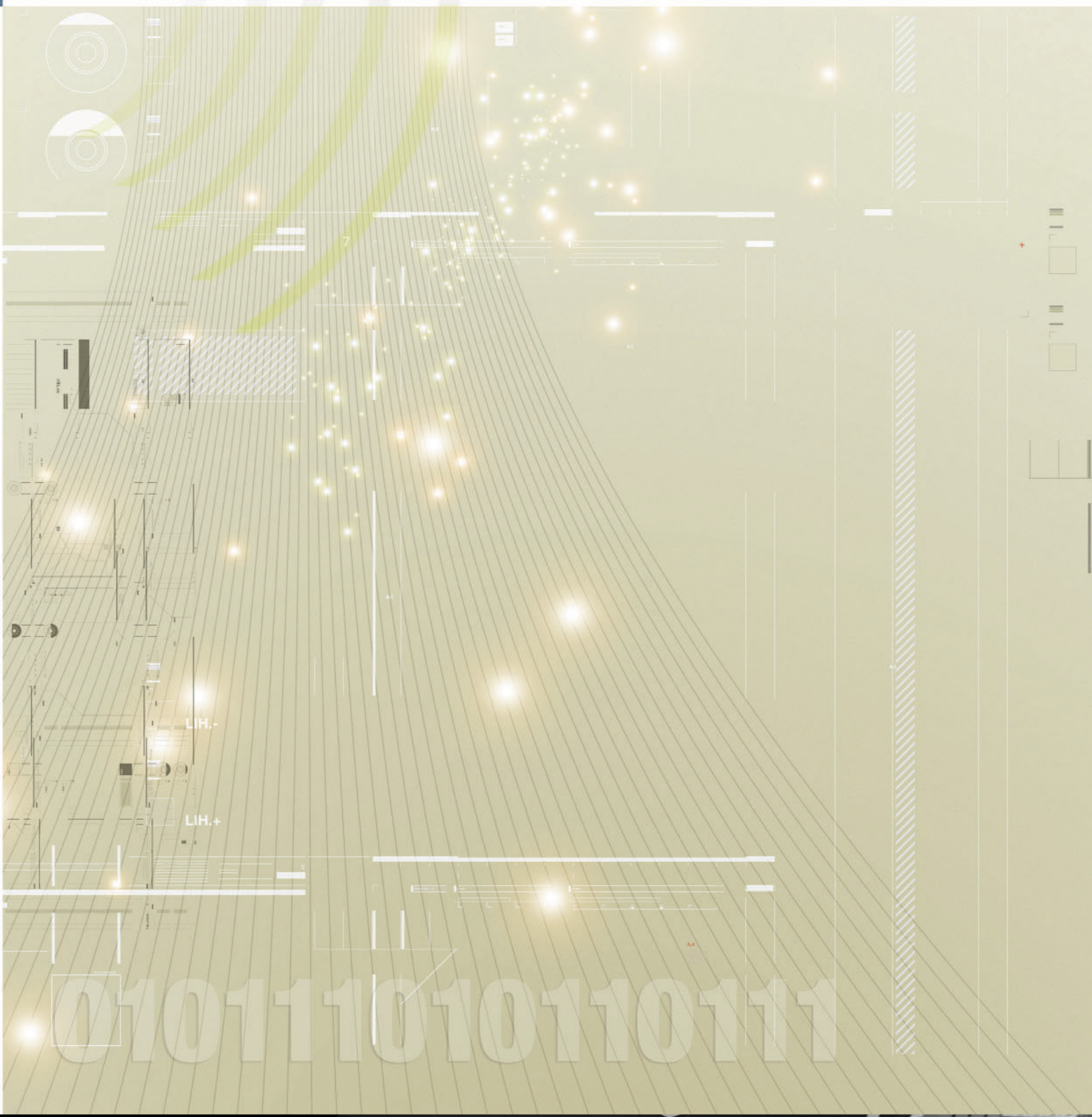
Lessons Learned

The following are key lessons learned from the JTRS program:

- Standardization is the basis for interoperability. Failure to achieve interoperability can result in severe consequences for the warfighter. JTRS standards will enable information interoperability to an unprecedented degree.
- Early and strong industry participation helps unleash the private-sector knowledge and technology to effectively address defense technology requirements. Industry participation resulted in a JTRS capability that is orders of magnitude better than the legacy systems it replaces by using almost entirely COTS solutions.
- Early involvement of industry and nongovernmental standardization bodies helps align commercial interests behind dual-use standardization solutions to satisfy system requirements and generate cost savings.

The involvement of several standards bodies ensured JTRS interoperability across the broad spectrum of diverse requirements and interests.

- Evolutionary development and designs that enable rapid change can keep systems perpetually aligned with state-of-the-art technology. This approach enables the JPO to identify the important technical issues, agree upon common definitions, create standards, and continuously improve the system over time.
- Using an open architecture can decrease system design costs, reduce system development time, facilitate interoperability, lengthen the system life cycle, reduce the risk of obsolescence, and drive down logistics, training, and maintenance costs. JTRS demonstrated that an open architecture also increases technological flexibility, opportunities for innovation, healthy competition, and the likelihood that the project's benefits extend well beyond its original objectives.



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